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Visualization of *in situ* spatial temperature distribution with transparent phantom containing thermo-chromic liquid crystals in millimeter waves exposure

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Abstract It is desired to evaluate the safety of millimeter-waves (MMWs) exposure to human bodies. Heating sources are induced within biological tissues by MMWs exposure. The influence of MMWs exposure to biological tissues is mainly based on this thermal effect. It is required to investigate the change of temperature distribution in biological tissues to operate MMWs safely. Accordingly, in this study, micro-encapsulated thermo-chromic liquid crystals (MTLCs) are introduced as temperature probes to observe the temperature distribution. We performed *in-vitro* experiments to visualize the temperature rise by 40 GHz MMWs exposure. In our presentation, we will show the results of temperature distribution with this non-destructive method.

Keywords Micro-encapsulated Thermo-chromic Liquid Crystal (MTLC), Phantom, Visualization, Millimeter-waves (MMWs), Spatial Temperature Distribution

1. Introduction

Millimeter-waves (MMWs) exposure to biological tissues causes temperature rise. The penetration depth of MMWs is smaller than 1 mm into the biological tissues [1]. Therefore, localized temperature rises are occurred by the highly concentrated power absorption within shallow area from the surface of the biological bodies. In order to measure this local temperature change, micro-encapsulated thermo-chromic liquid crystals are used as the method of temperature measurement [2].

MTLC have a characteristic that the wavelength of scattered light depends on the temperature. Therefore, by projecting a slit white light, it enables us to visualize the two-dimensional temperature distribution *in situ*. The MTLC-method has high spatial resolution because the diameter of MTLC is as small as about 20-30 μm. This method is fitted for measuring temperature distributions due to highly localized heating source.

The purpose of this report is to examine the usability of MTLC method in MMW frequency band exposures. We performed *in situ* experiments with gel phantom to visualize the temperature rise by 40 GHz MMWs exposure.

2. Experimental method

A gel phantom containing MTLCs is made for this experiment. The MTLC used in this experiment is toned depending on the temperature from 25 ℃ to 30 ℃. This MTLC scatters red light at 25 ℃ and scatters blue light at 30 ℃ for the observation angle of 90º to the incident direction of the slit light. This phantom is composed of 0.06 wt% MTLC, 2.0 wt% carrageenan, 30.0 wt% sucrose, 0.5 wt% KCL and 67.5 wt% water. It has a cuboid form with the size of 50 mm×50 mm×45 mm, and is sustained by itself without any container.

Figure 1 shows the block diagram of the exposure system that was used in this experiment. One of the lateral surfaces of the phantom is irradiated with 40 GHz MMWs using an open-ended waveguide. The distance between the phantom and the open-ended waveguide is 5 mm as shown in Fig.2 (b). We irradiated 40 GHz MMWs whose input power into the open-ended waveguide is 27.9 dBm. At this time, the power of reflected wave from the phantom was as small as -23 dBm.

The actual measurement setup is shown in Fig. 2 (a) by picture and relationship of each component position is shown in Fig. 2 (b) and (c). The phantom was illuminated with a slit light that is perpendicular to the direction of wave propagation, as shown in Fig.2 (b). The change of MTLC’s coloring was photographed by a digital camera which is PowerShot S100 manufactured by Canon. The slit light source was adjusted to the surface of the exposed plane as shown in Fig. 2 (b), because power absorption into phantom was limited localized region in the vicinity of the surface of the phantom.

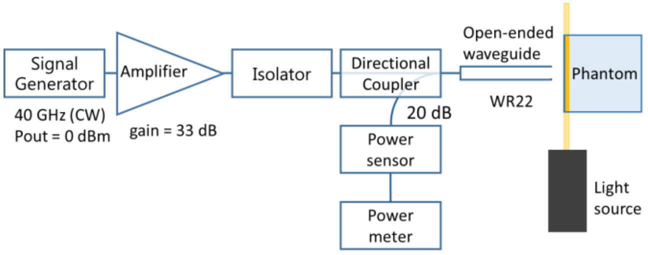

Fig. 1 Block diagram of the exposure system.

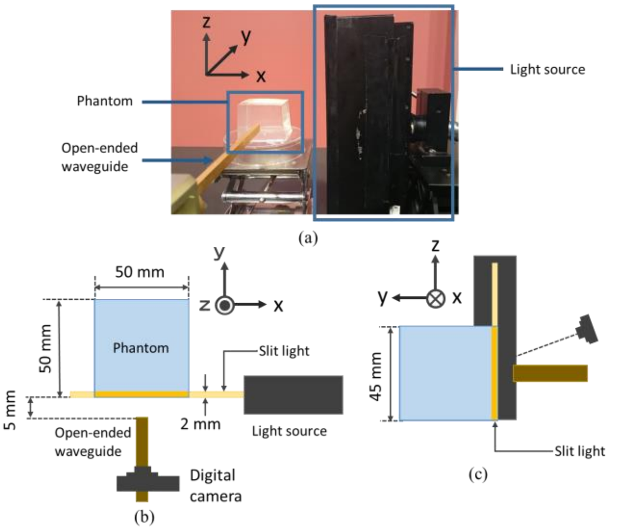

Fig. 2 Experimental condition.

3. Results and discussion

Figure 3 shows the pictures captured at t=0 s, 100 s, 200 s, 420 s, 460 s and 480 s. The origin of the time corresponded to the onset of the exposure, and the MMW exposure stopped at 420 s. The coloring region within the phantom expands as time goes on. Also, the center of the coloring region is blue, and the edge of the coloring region is red. The above results enable us to understand that the center has the highest temperature and the heat flux is oriented from the center to the edge in the coloring region.

4. Conclusion

We have visualized the highly localized temperature elevation by 40 GHz MMWs exposure with MTLC-method. We confirmed the usability of MTLC-method for the MMW exposure.

References

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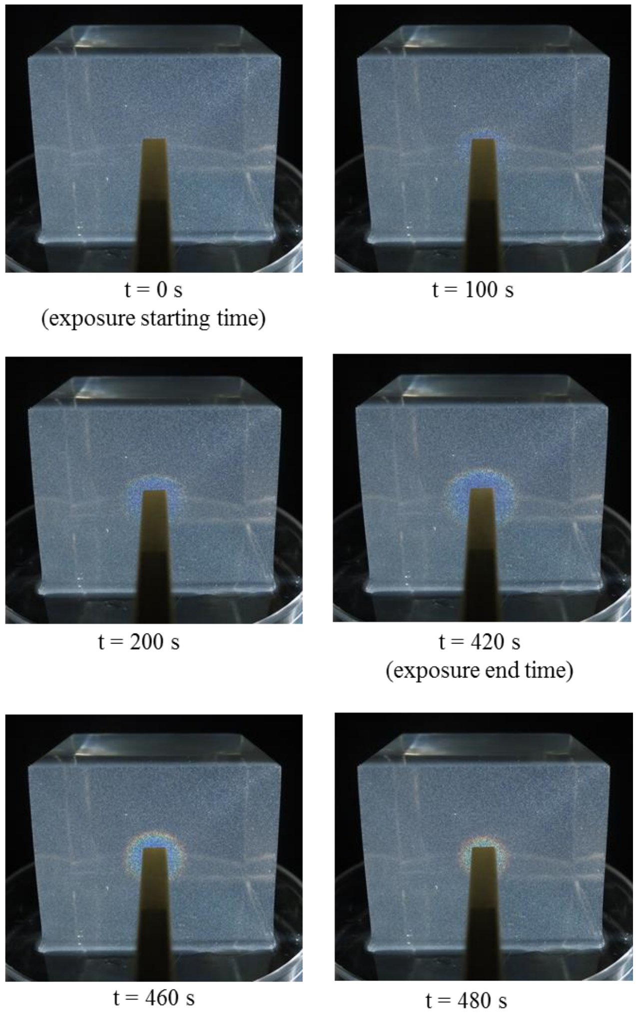

Fig. 3 Captured images at t=0 s (exposure starting time), 100 s, 200 s, 420 s (exposure end time), 460 s and 480s.